

BIOMASS AND CARBON SEQUESTRATION OF ACACIA MANGIUM WILLD PLANTATIONS AT DIFFERENT AGES IN THAI NGUYEN PROVINCE, VIETNAM

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ARTICLE INFO	ABSTRACT
Received: 10/5/2022	This study aimed to investigate the amount of carbon or carbon dioxide in <i>Acacia mangium</i> Willd plantations of different ages (2, 3, 4, 5, 6, 7 years old) in Thai Nguyen province, Vietnam. In this research, the total carbon sequestration of a plantation consists of the carbon stored in above ground tree biomass was assessed. A total of 54 sample trees were harvested and dissected into their components included boles, branches and leaves to weigh biomass and converted into carbon stock of <i>Acacia mangium</i> Willd. The result shows that the values of green biomass changed by years in the study site, which ranges from 27.08kg/tree to 127.7kg/tree and 60.12 tons to 156.42 tons/ha from 2-year to 7-year respectively. The dry biomass ranged from 29 to 79 ton/ha of observed age plantations. This study also found that the major contributor to total biomass and carbon stocks in <i>Acacia mangium</i> Willd plantation up to 7 years old was boles and followed by branches and leaves.
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KEYWORDS	
Biomass	
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SINH KHỐI VÀ KHẢ NĂNG HẤP THỤ CÁC BON CỦA RỪNG TRỒNG KEO TAI TƯỢNG (ACACIA MANGIUM WILLD) Ở CÁC ĐỘ TUỔI KHÁC NHAU TẠI TỈNH THÁI NGUYÊN, VIỆT NAM

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THÔNG TIN BÀI BÁO	TÓM TẮT
Ngày nhận bài: 10/5/2022	Nghiên cứu này nhằm điều tra lượng carbon hoặc carbon dioxide trong rừng trồng Keo tại tượng ở các độ tuổi khác nhau (2, 3, 4, 5, 6, 7 năm tuổi) tại tỉnh Thái Nguyên, Việt Nam. Trong nghiên cứu này, tổng lượng carbon hấp thụ của một lâm phần bao gồm carbon được lưu trữ trong sinh khối cây trên mặt đất đã được đánh giá. Tổng số 54 cây mẫu đã được thu hoạch và phân tách thành các thành phần của chúng bao gồm thân, cành và lá để lấy sinh khối và chuyển đổi thành trữ lượng carbon của cây keo tại tượng. Kết quả cho thấy giá trị sinh khối tươi thay đổi theo các năm tại địa điểm nghiên cứu, dao động từ 27,08kg/cây đến 127,7kg/cây và 60,12 - 156,42 tấn/ha từ 2 năm đến 7 năm. Sinh khối khô dao động từ 29 đến 79 tấn/ha rừng trồng theo tuổi nghiên cứu. Nghiên cứu này cũng chỉ ra rằng yếu tố đóng góp chính vào tổng sinh khối và trữ lượng carbon trong rừng trồng Keo tại tượng đến 7 năm tuổi là thân sau đó là cành và lá.
Ngày hoàn thiện: 24/6/2022	
Ngày đăng: 24/6/2022	
TỪ KHÓA	
Sinh khối	
Hấp thụ các bon	
Carbon dioxide	
Keo Tai Tượng	
Lâm phần	
Thái Nguyên	

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1. Introduction

Carbon sequestration in trees and soil as a means of minimizing atmospheric carbon stores is a concept that have been undervalued as a means to help mitigate global climate change [1]. In recent years, carbon sequestration in plant parts and soil in land use systems became an important area of research [2]. Carbon capture and storage may vary within different forest types and would depend on factors such as structure, age, vegetation, land-uses and management practices [3]. It was found out that reforestation and afforestation are effectively used as mitigation strategies, since combination of carbon (C) storage and wood production can occur at the same time [4]. Forest ecosystems are a particular focus of carbon accounting research because they represent the largest terrestrial ecosystem carbon stocks [5].

Plantations are becoming an important component of the world's forest resources and play a key role in the context of overall sustainable forest management [6].

Large-scale afforestation and reforestation have been proposed as a strategy to increase carbon sequestration [7].

Acacia mangium Willd is a native plant from Australia, Papua New Guinea, and Indonesia [8]. Plantation forest using fast growing species has been adopted in many countries as one option for a sustainable supply of tree products and also reducing the pressure on natural forest [9]. *Acacia mangium* Willd is an important multipurpose tree for the tropical lowlands. It is one of the most widespread of the fast-growing tree species which are used in plantation forestry programs throughout Asia, the Pacific and the humid tropics like Viet Nam [10]. *Acacia mangium* Willd has been playing an increasingly important role in efforts to sustain a commercial supply of tree products whilst reducing pressure on natural forest ecosystems. Fast-growing *Acacia* plantations provide industrial wood for Vietnam's wood-processing, pulp and paper industries and woodchip exports, as well as household fuelwood supplies in rural areas. Currently, 80% of the total requirement of Vietnam's wood-processing industries must be imported. *Acacia* plantations are also nitrogen fixing species and its leaves provide an effective litter layer, making the species a favored plantation genus in Vietnam [10].

At present, there is a limited number of studies on carbon sequestration in Thai Nguyen province, Vietnam, particularly *Acacia mangium* Willd plantations at all age levels. Therefore, this research provides additional information to scientists and forest managers on the carbon storage capacity of forest plantations regardless of suitable land and management practices.

2. Study site

This study was conducted in *Acacia mangium* Willd plantation in Dong Hy district, Thai Nguyen province, Vietnam where the *Acacia mangium* Willd dominated in forest plantation.

3. Methodology

The temporary sample plots were set up in the different conditions (strata) at top hill, side hill and bottom of plantation at each level of ages at 2, 3, 4, 5, 6, 7 for carbon stock estimation.

Totally, one hundred and eight (108) plots were established on six (06) levels of age (2, 3, 4, 5, 6, and 7) to estimate plantation carbon stock following by the different elevations (top hill, side hill and bottom of the plantation). 36 plots have been set up in the top, 36 plots in the middle and 36 plots in the bottom of plantation by age classes. In each level of age, 06 sample plots were established in top hill, 06 in middle hill, and 06 in bottom of the plantation.

Fifty-four (54) sampling trees at the different ages from the site selected for biomass and carbon sequestration randomly sampled and their height, diameters (H and D), fresh weight and volumes measured in the field. The trees were sampled to represent the known range of diameters for the species in the area for biomass and carbon estimation (Nine (09) sampling trees each age levels, three (03) trees per each elevation). Tree in the plot was divided into three (03) diameter

classes, (Big, medium, and small). The diameter class was followed the method of Vu Tien Hinh, 2012 [11], in the book of forest inventory in Vietnam (for plantation in Vietnam) and UN-REDD Vietnam in guide handbook for biomass estimation 2014.

The sample trees with the same or nearest mean of diameter and height of identified class in the sampled plot was fallen down and separated into boles (stem), branches and leaves to calculate the green biomass by weighting all the trees and its components in the field with the precision weight balance of 0.5 grams [11].

Green biomass of the sample tree was calculated as equation below:

$$\text{Green biomass} = W_{\text{boles}} + W_{\text{branches}} + W_{\text{leaves}}$$

where:

W_{boles} , W_{branches} , W_{leaves} are weight of boles, branches and leaves respectively in kg.

Dry biomass was calculated through the ratio of green biomass and dry biomass over green biomass (Figure 1) of each component. Dry biomass was identified by representative samples method as following:

Bole dry biomass: after dividing themselves into the different segments of each tree, three (03) samples were sliced at the top, middle and bottom of the trunk for calculation (03-05cm/slice).

Branch dry biomass: 0.5kg of sample of branch will be dried and calculated the weight

Leave dry biomass: mix all of leaves and take 0.5kg/tree as sample for biomass calculation.

The oven-drying machines used to dry the samples at temperature 105°C for a period of 6-8 hours. If after three times the weight of the test sample shows no change, it is the dry weight of the sample. Based on the dried weight, moisture each stems, leaves and branches will be determined by the following formula:

$$\text{MC (\%)} = [(GW - DW)/GW] * 100 (\%)$$

where:

MC is moisture content (%), and

GW, DW are green and dry weight respectively in kg.

Dry biomass of each component is calculated by the following formula;

$$DW_{(i)} = GW_{(i)} \times (1 - MC_i) \quad (\text{kg}) \quad \text{Where:}$$

$DW_{(i)}$, $GW_{(i)}$ are dry and green biomass of each component of tree as trunk, leaves, and branch respectively in kg, and

MC_i is moisture content of each tree components (%).

Total dry biomass of trees is calculated as follows:

$$DW_{(\text{tree})} = DW_{(\text{bole})} + DW_{(\text{branch})} + DW_{(\text{leave})} \quad (\text{kg/tree})$$

where: DW is dry weight.

This present study determined the carbon content of the *Acacia mangium* Willd trees:

$$\text{Carbon} = \text{Dry biomass} \times 50\%$$

$$\text{Or Carbon} = \text{Dry biomass} \times 0.5 \quad (\text{kg})$$

Method of determining CO₂ absorbed of forest plantation bases on the international conversion coefficient: $1C = 3.67CO_2$

$$CO_2 = C * 3.67 \quad (\text{kg } CO_2/\text{tree})$$

4. Result and discussion

4.1. Green Biomass of Individual Tree and Stands

The result of green biomass studies of *Acacia mangium* Willd at different ages in Thai Nguyen is summarized in Table 1. Table 1 shows the different green biomass by year of sample trees ranging from 2 to 7 aged sample trees averaged from 27.08 to 143.4kg/tree respectively and the strata of the study site which ranged from 26.86 to 143.37 kg/tree for bottom, the hillside and topside green weight ranged 28.63 to 141.57kg/tree and 25.73 to 142.43kg/tree respectively.

Mostly, the highest amount of biomass is at the bottom of the site, following are the hillside and top of the site at all year of plantation while at the 2-year, highest is at the hillside of the study site, and then at bottom and top of the site. Thus, there is a difference in growth at the different strata due to the nutrient and photosynthesis process [12].

The distribution of biomass in each sample tree showed the different values in boles, branches, leaves that presented in the Figure 2. Large part of biomass was stored in boles followed by branches and lastly leaves at different selected age plantations.

The bole is the major fresh biomass component of *Acacia mangium* Willd at all different ages classes, accounting for 59%, 63%, 65%, 73%, 76% and 74% of the total fresh biomass of the tree for the year 2, 3, 4, 5, 6 and 7 respectively. If this species is planted for paper purposes, this is a high yielding species.

Table 1. Average green biomass distribution (kg/tree)

Age	Place	Green biomass of sample trees			Total
		Bole (kg)	Branch (kg)	Leave (kg)	
2	Bottom	16.46	5.93	4.46	26.86
	Side	17.06	6.63	4.93	28.63
	Top	15.3	5.93	4.5	25.73
Average		16.28	6.17	4.63	27.08
3	Bottom	25.71	8.77	6.27	40.74
	Side	23.43	7.77	5.27	36.47
	Top	22.33	8.8	5.77	36.9
Average		23.83	8.44	5.77	38.04
4	Bottom	41.88	12.9	8.4	63.18
	Side	35.8	13.97	7.54	57.31
	Top	35.8	14.31	7.63	57.74
Average		37.83	13.73	7.86	59.41
5	Bottom	68.9	17.07	9.8	95.77
	Side	66.4	16.73	8.9	92.03
	Top	66.97	12.63	10.93	90.53
Average		67.42	15.48	9.88	92.78
6	Bottom	84.3	16.6	10.7	111.6
	Side	82.3	16.5	8.8	107.6
	Top	84.4	15.6	8.7	108.7
Average		83.7	16.2	9.4	109.3
7	Bottom	95.3	23	13.5	131.8
	Side	94	19.11	13.12	126.23
	Top	93	19	13.1	125.1
Average		94.1	20.4	13.2	127.7

Following is biomass of branches which are comprised of 23%, 22%, 22%, 16%, 15% and 14% of 2-year to 7-year of plantation. The lowest values are certainly of the leaves of the tree which are accounting for 18%, 15%, 13%, 11%, 9% and 10% of year 2, 3, 4, 5, 6 and 7 respectively. It is clearly that, as the year increases, the biomass increases as noted among *Acacia mangium* Willd in Thai Nguyen.

Sadeli Ilyas (2013) [13] indicated that, the contribution of bole, branch and leaf biomass of *Acacia mangium* were 67%, 19% and 14% respectively in East Kalimantan, Indonesia. According to Soulemene Traoré et al, 2017, the largest biomass was found in the boles followed by branches and leaves of *Acacia mangium* Willd. The results of this study showed that the boles stored on average of 60%, 72% and 80% of the total biomass in 3-year, 7-year and 11-year stands respectively [14].

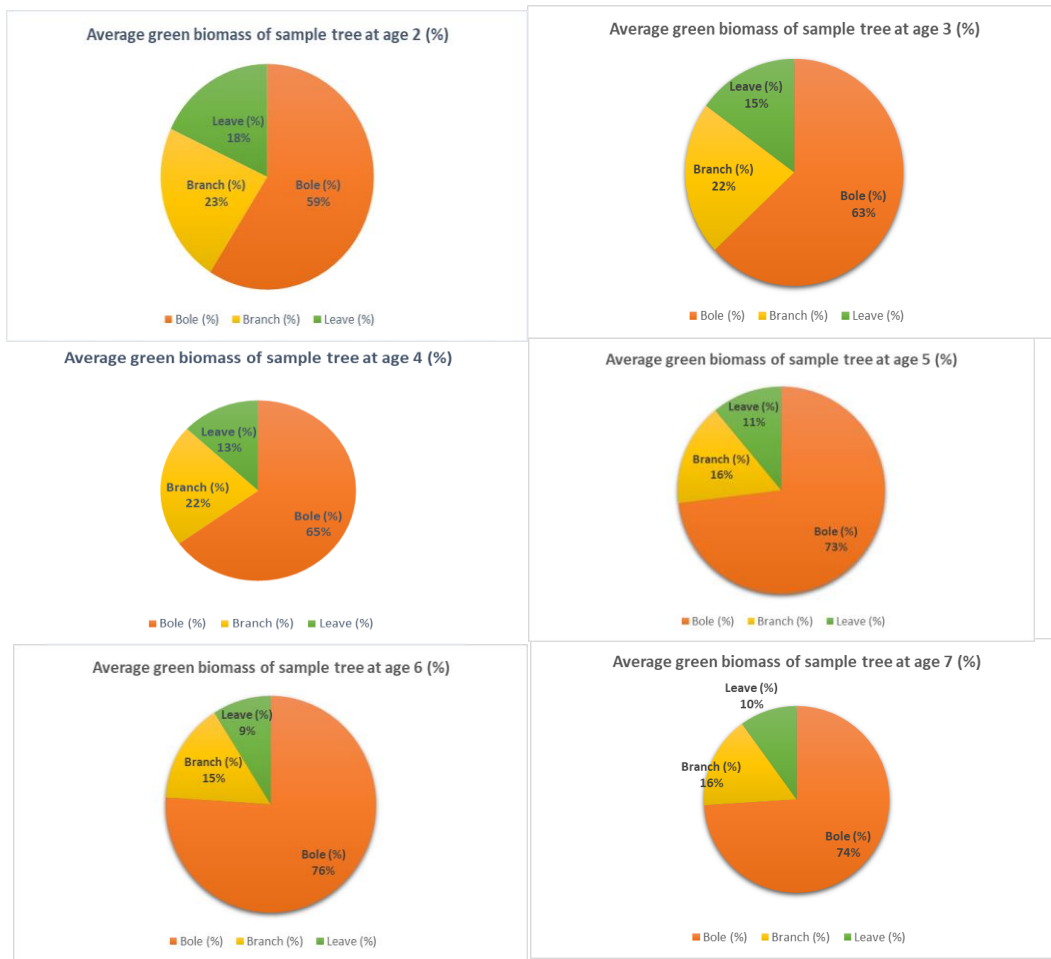


Figure 2. Biomass distributions in the tree components by ages (%)

In the research of Timothy J. Albaugh et al (2016) on biomass and nutrient mass of *Acacia dealbata* and *Eucalyptus globulus* plantations in Chile indicated that the stem component represented the highest portion of total mass for all species [15]. The values of green biomass changed by years in the study site, is ranging from 27.08kg/tree to 127.7kg/tree and 60.12 to 156.42 ton/ha from 2-year to 7-year respectively (Figure 4). Compare with the research of Chaw Chaw Sein et al (2011) [10] at *Acacia* species plantation in Phu Tho province from 1 to 7 year of ages indicated that, it is estimated that the specimens attained minimum increases in biomass of 1.3 tons at 1-year of age and maximum increases of 190.3 tons at 7 years of age, giving an average of 50.0 ton/ha for these plantations.

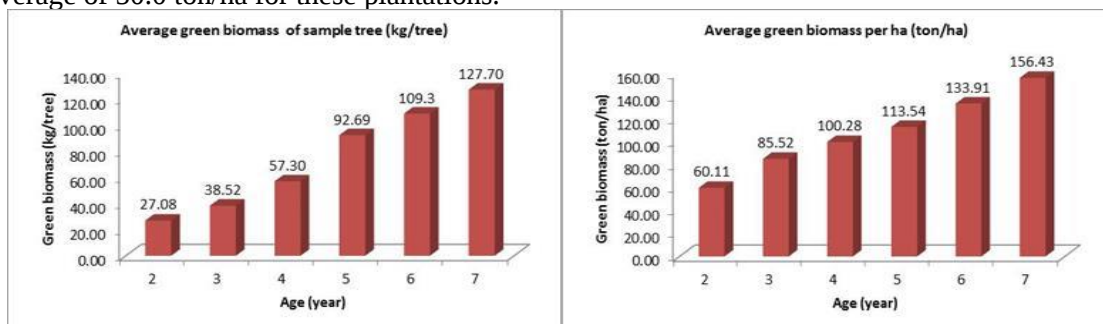


Figure 3. Average of green biomass by sample tree and stand by ages.

4.2. Dry biomass and carbon of individual trees and stands

Dry biomass of boles and branches are relatively high proportion in a tree and stand accounting for 63.8% (8.4kg/tree) and 22.10% (2.90kg/tree) at year 2 while the lowest is still biomass in leaves which is 14.38% (1.90kg/tree) (Figure 5).

The dry matter values increase by age as shown in year seven are 78% (50.24kg/tree), 14.65% (9.49kg/tree) and 7.60% (4.91kg/tree) in boles, branches and leaves respectively (Table and Figure). The dry biomass values for age 3, 4, 5, 6 at each component are (65.68, 22.04 and 12.29%); (67.28, 23.53 and 9.19%); (76.29, 15.94 and 7.77%); (79.80, 13.94 and 6.26%) respectively.

The values in Table 2 also indicate the difference among strata condition in terms of biomass calculation for whole-trees and their components. Mostly, the bottom site shows the largest values and following is the other places but it is less obvious differences.

The dry biomass of stand was obtained by multiplying the average sample tree with the current density. The average value of dry biomass per stand indicated in the Figure 4 shows the changing of the values by ages. The biomass ranged from 29 to 79 ton/ha.

Table 2. Average dry biomass distribution in the tree (kg/tree)

Age (year)	Place	Dry biomass of sample trees (kg)			Total
		Bole (kg)	Branch (kg)	Leave (kg)	
2	Bottom	8.73	2.67	1.68	13.13
	Side	8.82	3.1	2.3	13.84
	Top	7.66	2.94	1.72	12.48
Average		8.4	2.9	1.9	13.15
3	Bottom	13.62	4.3	2.73	20.64
	Side	11.25	3.97	1.98	17.2
	Top	11.24	3.8	2.08	17.11
Average		12.03	4.02	2.26	18.32
4	Bottom	23	5.46	2.9	31.36
	Side	18.65	7.15	2.55	28.35
	Top	16.11	7.18	2.4	25.69
Average		19.25	6.6	2.61	28.47
5	Bottom	36.63	8.23	3.51	48.37
	Side	35.63	7.61	2.96	46.2
	Top	30.53	5.75	3.88	40.16
Average		34.26	7.2	3.45	44.91
6	Bottom	45.05	7.83	3.72	56.59
	Side	41.18	7.5	3.18	51.86
	Top	43.65	7.34	3.31	54.3
Average		43.29	7.56	3.4	54.25
7	Bottom	50.1	9.78	4.84	64.72
	Side	53.2	9.17	5.04	67.4
	Top	47.41	9.53	4.87	61.8
Average		50.24	9.49	4.91	64.64

Table 3. Average carbon and carbon dioxide of sample trees and components

AGE (year)	CARBON SAMPLE TREE (kg)			CARBON (kg/tree)	CO ₂ (kg/tree)
	Bole	Branch	Leave		
2	4.20	1.45	0.95	6.61	24.24
3	6.17	2.01	1.09	9.27	34.02
4	9.62	3.30	1.31	14.22	52.19
5	16.85	3.58	1.71	22.14	81.25
6	23.40	3.80	1.70	28.90	106.06
7	25.12	4.75	2.46	32.32	118.62

Carbon stocks were calculated based on dry biomass of sample trees and stand. The values of carbon and carbon dioxide stocks vary from age to age. The average amount of carbon and carbon dioxide per individual tree are 6.61 and 24.24 kg/tree at year of age 2, the remaining years are 3, 4, 5, 6, and 7 are 9.27 and 34.02kg/tree; 14.52 and 52.19kg/tree; 22.14 and 81.25kg/tree; 28.90 and 106.06kg/tree; 32.32 and 118.62kg/tree respectively. The stem also obtains the largest amount of carbon and carbon dioxide among tree components. The 2- year plantation at average of 4.2; 1.45 and 0.95 kg of carbon in bole, branch and leave respectively, are noted. At the year of 7, the carbon was 25.12, 4.75 and 2.46kg/tree of tree components as bole, branch and leave respectively (Table 3). The growth of carbon and carbon dioxide by ages increased averagely at 28.7% per year.

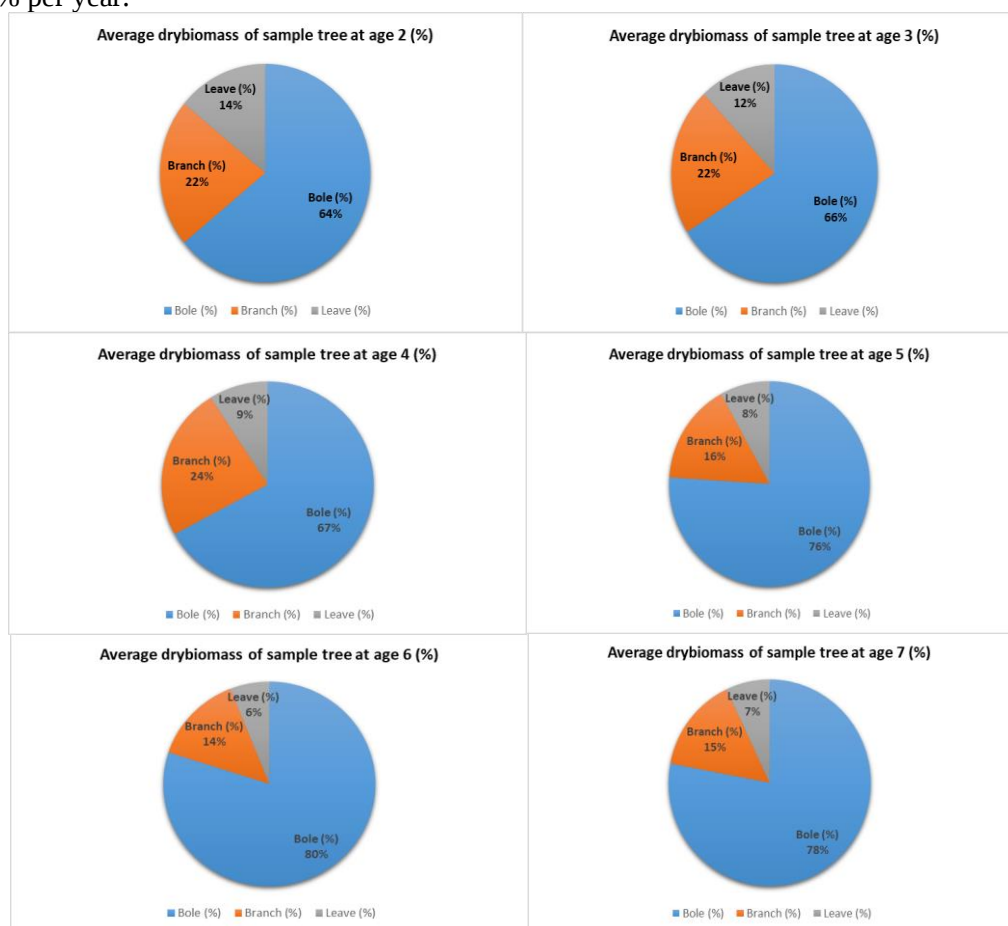


Figure 4. Dry biomass distribution in sample tree components (%) by ages

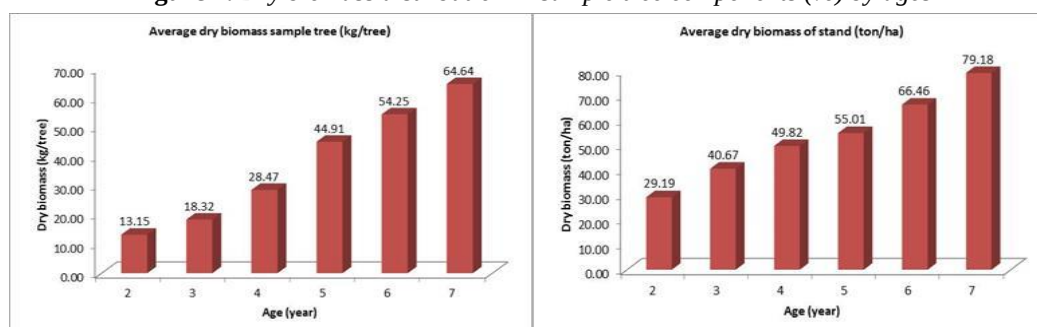


Figure 5. Average dry biomass of sample trees (kg/tree) and stand (ton/ha) by ages

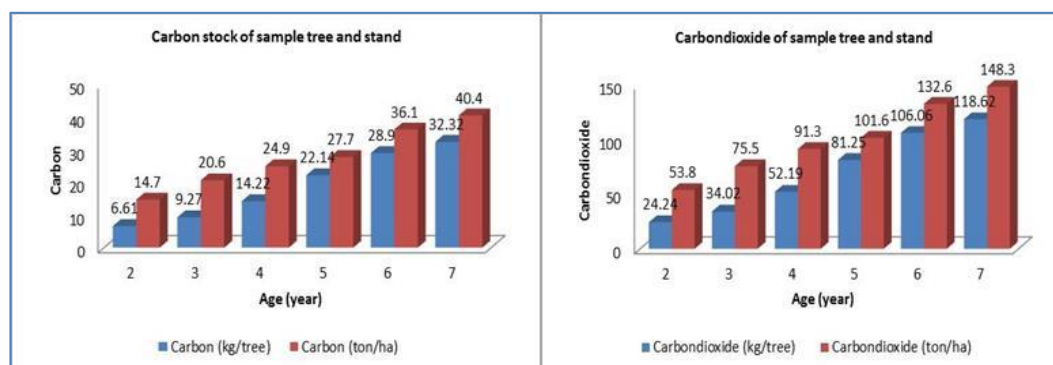


Figure 6. Carbon and carbon dioxide sample tree and stand

In comparison with other studies, the research of Irma Herdiyanti 2016, shows that the amount of carbon stocks (all carbon pools aboveground) of *Acacia mangium* Willd was 44.87 Mg/ha, 73.53 Mg/ha, 77.81 Mg/ha, and 72.88 Mg/ha for 1, 3, 5, and 7 year-old stands respectively in Indonesia [16]. This difference may due to many reasons such as location, weather conditions, soil nutrients, silvicultural approaches, density, source of species, and management practices.

The research on biomass and carbon of *Acacia mangium* and *Acacia auriculiformis* at Makiling area, Los Banos, laguna, Philippines, by Combalicer et al (2011) showed that the carbon stock of *Acacia mangium* tree was 91.47 tons/ha at the years of age 20, and total carbon stock was 93.69 tons/ha [17]. The value of *Acacia auriculiformis* at 10 and 20 years were 29.50 and 68.65 tons/ha for tree and for total biomass were 32.34 and 70.60 tons/ha respectively.

5. Conclusion

In this study it was estimated the biomass and carbon content of different tree compartments of *Acacia mangium* Willd plantation in Thai Nguyen province, Vietnam.

The green biomass of *Acacia mangium* Willd indeed varies according to ages. The major biomass in the tree and stand are boles, following are branch and leaves. The total average green biomass of one hectare of *Acacia mangium* Willd in Thai Nguyen province at different ages were 60.12, 84.45, 103.97, 113.66, 133.89 and 156.42 ton/ha for the age of 2, 3, 4, 5, 6, and 7 respectively.

Total average dry biomass of one hectare of *Acacia mangium* Willd were 29.19, 40.67, 49.8, 55.0, 66.4 and 79.1 ton/ha for the year 2, 3, 4, 5, 6, and 7 respectively. The total carbon ranged from 14.9 to 40 ton/ha at the age of 2 and 7.

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